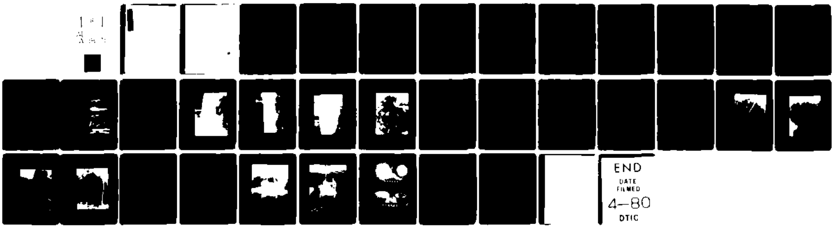
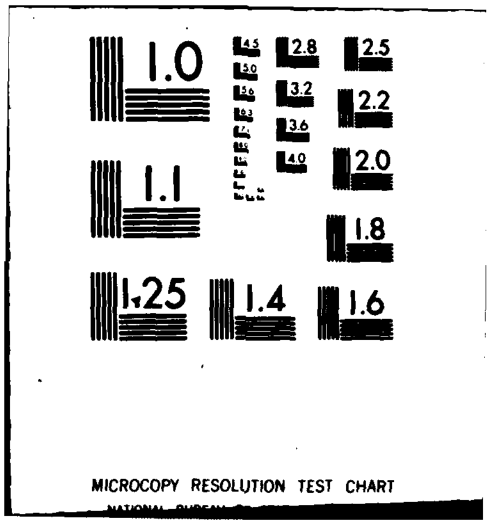
AD-A081 712 NAVAL SURFACE WEAPONS CENTER DAHLGREN VA F/G 11/4
BURN/BLAST TESTS OF MISCELLANEOUS GRAPHITE COMPOSITE PARTS.(U)
NOV 79 T C BABINSKY, K A MUSSELMAN
UNCLASSIFIED NSWC/TR-79-390 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NSWC TR 79-390	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) BURN/BLAST TESTS OF MISCELLANEOUS GRAPHITE COMPOSITE PARTS		5. TYPE OF REPORT & PERIOD COVERED FINAL
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) T. C. Babinsky K. A. Musselman		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Surface Weapons Center (G50) Dahlgren, VA 22448		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 64215N;W0852;W0852000
11. CONTROLLING OFFICE NAME AND ADDRESS National Aeronautics and Space Adminstration, Langley Research Center Hampton, VA 23665		12. REPORT DATE November 1979
		13. NUMBER OF PAGES 36
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

HAVE NAME risk assessments
Burn/blast tests
Graphite composite parts testing
C-4 Harrisite explosive

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the work performed by the Naval Surface Weapons Center on tests conducted for NASA, Langley Research Center for a series of burn/blast tests with various graphite-reinforced composite materials and aircraft components. These tests were a continuation of a series requested by NASA, and, as in previous tests, information concerning the effects of fire and/or explosion upon aircraft structural composite materials and size distribution and dissemination patterns of released fiber materials for

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. (Continued)

risk analyses was obtained. Electrical hazards associated with the released fibers should be the same with these materials as with previously tested materials, but final risk assessment is dependent also on other factors being investigated under the overall NASA program.

FOREWORD

The work described in this report was performed by personnel of the Materials Science Branch, Survivability and Applied Science Division, Weapons Systems Department. The test participation was part of an aircraft structural parts test program (L 62936A) sponsored by NASA, Langley Research Center. This report details the work and presents the results of tests conducted with both proposed and in-use aircraft parts and structural material. The data from this work were used by NASA in their carbon fiber accidental release risk analysis.

This document has been reviewed by C. E. Gallaher, Navy Program Manager of the Electromagnetic Effects Division, Electronics Systems Department; J. D. Hall, Head, Materials Science Branch, Weapons Systems Department; and D. S. Malyevac, Head, Survivability and Applied Science Division, Weapons Systems Department.

Released by:

CDR R. P. *FUSCALDO*
Assistant for Weapons Systems
Weapons Systems Department

CONTENTS

TABLES

ILLUSTRATIONS

INTRODUCTION

This report documents the details of the experimental setup, a brief description of the materials tested, and the results from a series of burn/blast tests conducted with various graphite-reinforced composite materials or airframe components. These tests were a continuation of the work requested by NASA, Langley Research Center (LaRC) on HAVE NAME risk assessment evaluations of aircraft structural elements. In this work basic material evaluations were made with test panels of typical construction material, and specific comparisons were made by testing some typical structural pieces. As in previous tests, the following information was sought: (1) the effects of fire and/or explosion upon aircraft structural composite materials and (2) size distribution and dissemination patterns of released fiber materials from these tests for risk analyses (to be performed elsewhere).

EXPERIMENTAL

The test fixture, propane burner, sample holder, and explosive charge container were the same as used in the previously reported AS 3501-6 composite[1] and aircraft structural elements[2] test series (see Appendix A). Other parameters similarly used were the sticky paper, petri dish sampling plan, and general cleanup procedures for particle identification.

The explosive weight and type selected for all the tests reported herein was 57 g (2 oz) of C-4 (Harrisite), as used in the previous test work.[1,2] The material (C-4) was loaded into an inverted conical shape interior explosive holder. This holder weighed approximately 11.35 kg (25 lb) and was designed to direct the blast evenly at the sample. The explosive holder was positioned 15.2 cm (6 in.) beneath the sample.

RESIDUE COLLECTION

The same 0.91-m (3-ft) grid layout used in previous tests was used to locate both petri dishes and sticky paper for residue fallout collection and to aid in released material dissemination pattern reconstruction. A total of 108 adhesive-backed poly(ethylene terephthalate) sheets (sticky papers) and 24 petri dishes were placed on the test compartment floor for each test. Figure 1 shows the petri dish and sticky paper location with respect to the compartment grid plan. Note that sticky paper samples 106 through 108 were placed on vertical surfaces, not on the floor.

The test compartment cleanup for residue recovery was the same for each test and followed the sequence of (1) petri dish recovery, (2) hand pickup of large residue pieces, (3) sticky paper recovery, (4) broom sweep of entire

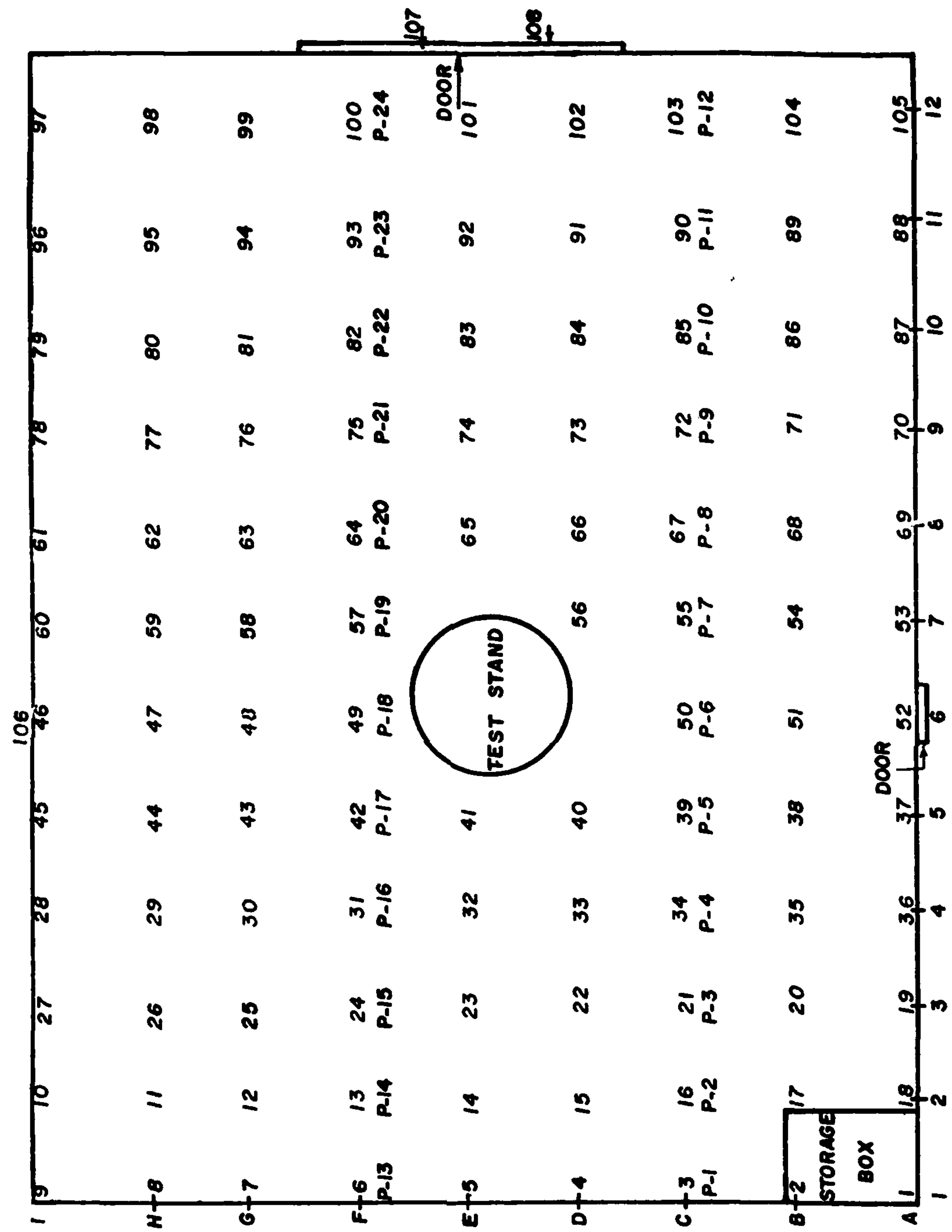


Figure 1. Sticky Paper and Petri Dish Layout

compartment floor, and finally, (5) power vacuum cleanup of remaining residue (entire compartment).

STICKY PAPER ANALYSIS

Of the 38 tests summarized in this report, 23 were analyzed for particle distribution as determined by sticky paper samples. One quadrant of the chamber compartment, represented by 29 papers per test, was sent to Dugway Proving Ground (DPG). Personnel at DPG conducted the counting analyses and provided the data summarized in Tables 1 and 2. The total counts of single fibers represent the amount extrapolated to be present in the entire test compartment.

TEST COMPONENT DESCRIPTION

In general, the test specimens evaluated in this report consisted of airframe structural parts (either actual in-use specimens or research prototypes) and test panels of various composite compositions/thicknesses.

The Quiet Clean Short-Haul Experimental Engine (QCSEE) inner cowl is a demonstration panel, which surrounds the core of this engine, and consists of T-300 graphite/PMR 15 resin with unspecified amounts of HRH-327 glass/Polyimide honeycomb.

The vertical rudder stiffener, aft vertical fin stiffener, and T-section skin-to-spar were all pieces of an L-1011 aircraft constructed of T-300 graphite cloth and Narmco 5209 epoxy resin. The various pieces were cut to accommodate the size of the test fixture sample holder.

The QCSEE fan blade consisted of various layers of KEVLAR (polyaramid fiber), S-glass, AS graphite, and boron with a 3M PR288 resin matrix system. The composite composition of the different materials was not available to the test group.

The NASA Lewis Research Center (LeRC) high tip speed fan blade was an AS graphite/PMR-11 resin system component from an experimental LeRC fan blade.

The Fiberite panel tested was a 14-ply laminate of W-134 graphite and MXG 6070 modified phenolic resin. This was an experimental formulation proposed as an alternate to the T-300 tape/weave combination being studied by the Air Force and Navy. This is a product of the Fiberite Corporation of Orange, California.

The floorboard panel was a United Kingdom product of Bristol, Ltd., with two plies covering a NOMEX honeycomb. This material is a sample of a composite in use on several European models of the Boeing 747 aircraft.

Table 1. Single Fiber Particle Analysis*, Miscellaneous Parts

Test No.	Burn Time (min.)	Total Count, Single Fibers	Mean Length (mm)	Standard Deviation (Length, mm)
BT-144/X-112	20	29,691,449	2.1	1.0
BT-145/X-113	20	101,373,712	2.5	1.6
BT-163/X-127	20	54,838,522	3.0	1.9
BT-164/X-128	20	19,891,457	2.8	1.7

* Analysis and particle counting done by Dugway Proving Ground personnel.

Table 2. Single Fiber Particle Analysis*, Flat Plates and Panels

Test No.	Burn Time (min.)	Total Count, Single Fibers	Mean Length (mm)	Standard Deviation (Length, mm)
BT-153/X-117	20	3,234,789	2.2	1.0
BT-160/X-124	20	2,693,535	3.4	2.2
BT-167/X-131	20	2,750,840	3.1	1.8
BT-168/X-132	20	2,151,920	4.7	4.6
BT-169/X-133	20	1,038,750	3.0	2.5
BT-171/X-134	20	5,088,960	2.9	1.6
BT-172	20	80,994	1.8	1.0
BT-182	20	22,147	1.9	1.0
BT-183/X-141	20	2,256,205	2.4	1.4
BT-184/X-142	20	8,999,790	2.4	1.2
BT-203	20	94,836	2.2	1.6
BT-205/X-156	20	24,576,867	3.8	2.5
BT-206/X-157	20	18,866,452	3.5	2.0
BT-185/X-143	20	21,301,500	3.0	1.9
BT-187	20	114,558	2.0	1.3
BT-188/X-144	20	23,680,310	3.2	2.4
BT-189/X-145	20	10,117,170	2.5	1.5
BT-190	20	48,600	1.8	1.0
BT-191/X-146	20	4,324,760	2.0	0.8

* Analysis and particle counting done by Dugway Proving Ground personnel.

The NCNS test plate was six plies of AS graphite with a Ciba-Geigy (13P) n-cyano-n-sulfanamide matrix.

The final test plates were a series of 0.16-cm (0.0625-in.), 0.32-cm (0.125-in.), and 0.65-cm (0.250-in.) thick AS/3501-6 LaRC-fabricated panels of both unidirectional and crossply construction. These panels were constructed from 30-cm (12-in.) wide tape with 12, 24, and 48 plies for the three thicknesses. The resin content for the three uniply panels was 35.1, 0.32, and 0.64 percent by weight for the 0.16-, 0.32-, and 0.64-cm samples, respectively. The corresponding resin content for the crossplied specimens was 32.9, 35.6, and 35.7 percent, respectively.

RESULTS AND DISCUSSION

MISCELLANEOUS PARTS

Table 3 shows the general test parameters of the miscellaneous fabricated composite parts. The breakdown of the test residue recoveries is given in Table 4 for these materials. A rough estimate of the total amount of each type of residue from each test was made and is summarized in Table 5. The

Table 3. *Test Parameters, Miscellaneous Parts*

Test No.	Part	Material	Part Size (cm)	Burn Time (min)	Temperature (°C)*
BT-144/X-112	QCSEE Inner cowl	T-300/PMR15/honeycomb	23 x 23	20	1076
BT-145/X-113	Vertical rudder stiffener	T-300/5209 epoxy	18 x 30	20	1096
BT-150/X-114	Aft vertical fin stiffener	T-300/5209 epoxy	18 x 20	20	1150
BT-161/X-125	Aft vertical fin stiffener	T-300/5209 epoxy	18 x 20	10	968
BT-162/X-126	Aft vertical fin stiffener	T-300/5209 epoxy	18 x 20	5	1148
BT-165/X-129	Aft vertical fin stiffener	T-300/5209 epoxy	18 x 20	3	1096
BT-166/X-130	T-Section skin-to-spar	T-300/5209 epoxy	17 x 26	20	1122
BT-163/X-127	QCSEE fan blade	Kevlar/AS/Glass/B/PR	24 x 29	20	1204
BT-164/X-128	LeRC high tip speed fan blade	AS graphite/PMR-11 resin	19 x 25	20	1204

* Temperture measured 1.3 cm (0.5 in.) below the outer edge of sample.

Table 4. Miscellaneous Parts: Recovery Breakdown of Burn/Explosion Tests

Test No.	Part	Material	Part Wt. (g)	Percent of Weight Recovered	Percent of Total Recovered Hand	Broom	Vac.
BT-144/X-112	QCSEE Inner cowl	T-300/PMR15/honeycomb	180.6	84.1	2.4	64.2	33.4
BT-145/X-113	Vertical rudder stiffener	T-300/5209 epoxy	1387.5	81.1	38.8	56.0	5.2
BT-150/X-114	Aft vertical fin stiffener	T-300/5209 epoxy	211.6	72.8	1.2	60.9	37.9
BT-161/X-125	Aft vertical fin stiffener	T-300/5209 epoxy	205.0	59.9	1.0	52.6	46.4
BT-162/X-126	Aft vertical fin stiffener	T-300/5209 epoxy	311.2	64.9	6.2	63.3	30.5
BT-165/X-129	Aft vertical fin stiffener	T-300/5209 epoxy	212.2	90.1	2.9	66.9	30.2
BT-166/X-130	T-Section skin-to-spar	T-300/5209 epoxy	516.3	70.6	45.6	36.9	17.5
BT-163/X-127	QCSEE fan blade	Kevlar/AS/Glass/B/PR 288 resin	693.7	70.9	19.6	65.2	15.2
BT-164/X-128	LeRC high tip speed fan blade	AS graphite/PMR-11 resin	687.8	86.5	31.1	58.6	10.3

Table 5. Miscellaneous Parts: Category Distribution Estimates, Percent by Weight From Burn/Explosion Tests

Test	Part	Material	Category* 1	2	3	4	5	6
BT-144/X-112	QCSEE Inner cowl	T-300/PMR15/honeycomb	25	5	30	8	0	32
BT-145/X-113	Vertical rudder stiffener	T-300/5209 epoxy	15	2	5	0	0	78
BT-150/X-114	Aft vertical fin stiffener	T-300/5209 epoxy	25	12	34	29	0	0
BT-161/X-125	Aft vertical fin stiffener	T-300/5209 epoxy	11	4	58	27	0	0
BT-162/X-126	Aft vertical fin stiffener	T-300/5209 epoxy	12	3	57	25	0	3
BT-165/X-129	Aft vetical fin stiffener	T-300/5209 epoxy	10	2	53	20	5	10
BT-166/X-130	T-Section skin-to-spar	T-300/5209 epoxy	8	2	25	23	7	35
BT-163/X-127	QCSEE fan blade	Kevlar/AS/Glass/B/PR 288 resin	10	5	45	20	15	5
BT-164/X-128	LeRD high tip speed fan blade	AS graphite/PMR-11 resin	8	2	27	5	11	47

* See Figure 2.

six category groupings, as in the previously reported work,[1] are as follows: (1) free fibers; (2) lint; (3) brush-clumps; (4) blast fragments < 2mm wide; (5) blast fragments, 2-7mm wide; and (6) laminar pieces (see Figure 2). Four of these elements that were tested had sticky paper particle counting analyses done at DPG, with results reported in Table 1.

There were no burn-only tests, for weight loss information, performed on these specimens because of the limited number of each type. The total residue recovery for the aft vertical fin stiffener samples provides some indication of weight loss versus burn time (Table 4). The 90-percent weight recovery after only a 3-min burn time followed by the explosive blast of

CATEGORY

1. SINGLE FIBERS

2. LINT

3. BRUSH/CLUMP

4. BLAST FRAGMENTS
   WIDTH < 2 mm

5. BLAST FRAGMENTS
   WIDTH 2-7 mm
   LENGTH < 25.0 mm

6. LAMINAR
   WIDTH > 7 mm
   LENGTH > 17.0 mm

Figure 2. Category Distribution Definition

BT-165/X-129 indicates only partial matrix consumption in that test. Other weight recoveries varied but were somewhat similar to those found in our earlier work with AS/3501-6 plates[1] and aircraft structural elements.[2] Since there were no data available regarding the matrix/reinforcement composition, specific conclusions as to the effect on weight loss and particle size distribution could not be made. In general, the data presented in Table 5 show that tests in which larger pieces of residue were recovered (i.e., category 6) there were smaller amounts of single fibers also recovered from that particular test specimen. The total single fibers count from test BT-145/X-113, as shown in Table 1, is consistent with the size of this sample when compared with others in this group. Again, the varying composition and construction of this group of samples make comparisons valid only in a limited manner.

Figures 3 through 6 show some typical examples of the types of residues produced by the burn/blasts to which these materials were subjected.

FLAT PLATES AND PANELS

The same type of data shown in the previous section for the miscellaneous parts is presented in Tables 2, 6, 7, 8, and 9 for the flat plates and panels. Table 9 gives the weight losses experienced by the AS/3501-6 samples of unidirectional and crossply materials after 20 min of burn only. There were more duplicate tests run with this group of specimens because of the availability of more material than with the others.

The weight recoveries were more uniform for this group than for those mentioned above. Two tests, BT-151/X-115 (Fiberite panel) and BT-178/X-138 (NCNS test plate), produced greater residue recovery weights than the original sample weights. These test results may be explained by the following: (a) BT-151/X-115 was run after the compartment was washed down, and some excess debris remained on the floor prior to this test, (b) the sample used in test BT-178/X-138 was extremely light (44.4 g). Thus the 10% excess recovered represents only 4.4 g (i.e., 0.01 lb). The floorboard panel sections were very light, and all total weight recoveries were fairly uniform for each, regardless of their respective burn times (Tables 6 and 7).

The small amounts of material in the AS/3501-6 plates made correlation difficult between the weight losses shown in the burn tests (Table 9) with the recovery weights given in Table 7. However, these did seem to follow the results obtained earlier in our rudder and spoiler structural elements testing.[2] The category distribution estimates shown in Table 8 closely parallel those tests also, especially when the effects of the fiberglass and other added materials present in the aircraft structural elements are disregarded. As shown in Table 9, the thinner samples gave a wider variability in the actual weight loss versus the matrix percentage. Also, the crossply material was usually more stable than the unidirectional type in that its weight loss more nearly approximated the theoretical.

Figure 3. Residue from Test BT-161/X-125, Aft Vertical Fin Stiffener

Figure 4. Residue from Test BT-163/X-127, QCSEE Fan Blade

Figure 5. Residue from Test BT-164/X-128, LeRC Fan Blade

Figure 6. Residue from Test BT-166/X-130, T-Section Skin-to-Spar

Table 6. Test Parameters, Flat Plates and Panels

Test No.	Part	Part Size (cm)	Burn Time (min)	Temperature (°C)
BT-151/X-115	Fiberite panel	15 x 15 x 0.32	10	1150
BT-152/X-116	Fiberite panel	15 x 15 x 0.32	5	1136
BT-153/X-117	Fiberite panel	15 x 15 x 0.32	20	1110
BT-154/X-118	Fiberite panel	15 x 15 x 0.32	10	1124
BT-155/X-119	Floorboard panel	15 x 15 x 0.96	1	1018
BT-156/X-120	Floorborad panel	15 x 15 x 0.96	3	1018
BT-157/X-121	Floorboard panel	15 x 15 x 0.96	5	1096
BT-158/X-122	Floorboard panel	15 x 15 x 0.96	10	967
BT-159/X-123	Floorboard panel	15 x 15 x 0.96	3	1150
BT-160/X-124	Floorboard panel	15 x 15 x 0.96	20	1102
BT-178/X-138	NCNS test plate	15 x 15 x 0.16	5	1122
BT-167/X-131	Unidirectional test plate	15 x 15 x 0.16	20	1232
BT-168/X-132	Unidirectional test plate	15 x 15 x 0.16	20	1122
BT-170	Unidirectional test plate	15 x 15 x 0.16	20	1070
BT-169/X-133	Crossplied test plate	15 x 15 x 0.16	20	1122
BT-171/X-134	Crossplied test plate	15 x 15 x 0.16	20	1096
BT-172	Crossplied test plate	15 x 15 x 0.16	20	1070
BT-182	Crossplied test plate	15 x 15 x 0.32	20	1100
BT-183/X-141	Crossplied test plate	15 x 15 x 0.32	20	1100
BT-184/X-142	Crossplied test plate	15 x 15 x 0.32	20	1076
BT-203	Unidirectional test plate	15 x 15 x 0.32	20	1070
BT-205/X-156	Unidirectional test plate	15 x 15 x 0.32	20	1108
BT-206/X-157	Unidirectional test plate	15 x 15 x 0.32	20	1106
BT-185/X-143	Unidirectional test plate	15 x 15 x 0.64	20	1122
BT-187	Unidirectional test plate	15 x 15 x 0.64	20	1150
BT-188/X-144	Unidirectional test plate	15 x 15 x 0.64	20	1162
BT-189/X-145	Cross-plied test plate	15 x 15 x 0.64	20	1096
BT-190	Cross-plied test plate	15 x 15 x 0.64	20	1122
BT-190	Cross-plied test plate	15 x 15 x 0.64	20	1122
BT-191/X-146	Cross-plied test plate	15 x 15 x 0.64	20	1096

Table 7. Flat Plates and Panels: Recovery Breakdown of Burn/Explosion Tests

Test No.	Part Wt. (g)	Percent of Wt. Recovered	Percent of Total Recovered: Hand	Broom	Vac.
BT-151/X-115	112.0	103.8	0	70.3	29.7
BT-152/X-116	107.8	89.1	1.0	60.7	38.2
BT-153/X-117	109.6	73.7	0	51.5	48.5
BT-154/X-118	106.4	79.8	1.1	57.1	41.8
BT-155/X-119	63.5	79.7	2.0	54.5	43.5
BT-156/X-120	63.1	68.5	1.6	46.1	52.3
BT-157/X-121	64.4	67.6	0	41.9	58.1
BT-158/X-122	64.2	57.0	0	34.2	65.8
BT-159/X-123	63.4	60.1	0	38.8	61.2
BT-160/X-124	64.3	56.5	0	35.6	64.4
BT-178/X-138	44.4	110.1	0	44.8	55.2
BT-167/X-131	56.9	87.2	0	48.6	51.4
BT-168/X-132	56.7	79.7	4.0	46.9	49.1
BT-169/X-133	56.9	69.2	0	32.2	67.8
BT-171/X-134	57.2	82.3	0	37.8	62.2
BT-183/X-141	104.1	72.1	0	51.6	48.4
BT-184/X-142	102.6	70.5	0	50.8	49.2
BT-205/X-156	112.7	83.4	0	46.8	53.2
BT-206/X-157	111.7	72.2	0	43.5	56.5
BT-185/X-143	221.8	68.1	0.1	69.9	30.0
BT-188/X-144	224.9	75.2	0	70.9	29.1
BT-189/X-145	207.8	74.5	0	69.9	30.1
BT-191/X-146	211.7	71.7	0	67.6	32.4

Table 8. Flat Plates and Panels: Category Distribution Estimates, Percent by Weight From Burn/Explosion Tests

Test	Category* 1	2	3	4	5	6
BT-151/X-115	15	5	5	40	25	10
BT-152/X-116	15	5	0	40	35	5
BT-153/X-117	15	5	25	25	25	5
BT-154/X-118	15	5	30	20	28	2
BT-155/X-119	15	5	25	25	20	10
BT-156/X-120	8	2	20	70	0	0
BT-157/X-121	5	5	40	50	0	0
BT-158/X-122	10	5	45	(40 Soot)	0	0
BT-159/X-123	5	5	20	10	(60 Soot)	0
BT-160/X-124	5	5	10	(80 Soot)	0	0
BT-178/X-138	20	10	25	20	(25 Soot)	0
BT-167/X-131	5	5	30	15	(25 Soot)	20
BT-168/X-132	5	5	25	20	(25 Soot)	20
BT-169/X-133	5	5	15	0	(75 Soot)	0
BT-171/X-134	5	5	25	0	(65 Soot)	0
BT-183/X-141	10	5	35	0	(50 Soot)	0
BT-184/X-142	20	10	20	15	(20 Soot)	15
BT-205/X-156	20	15	25	0	(40 Soot)	0
BT-206/X-157	20	15	30	0	(35 Soot)	0
BT-185/X-143	20	10	30	10	(30 Soot)	0
BT-188/X-144	20	12	30	8	(30 Soot)	0
BT-189/X-145	20	10	25	20	(25 Soot)	0
BT-191/X-146	15	10	25	12	(38 Soot)	0

* See Figure 2.

Table 9. Burn Test Results, AS3501-6 Plates

Test No.	Type	Thickness (cm)	Matrix, % by Wt.	Wt. Loss (%)
BT-170	Unid	0.16	35.1	56.5
BT-172	Xply	0.16	32.9	40.4
BT-182	Xply	0.32	35.6	26.4
BT-203	Unid	0.32	26.7	56.5
BT-187	Unid	0.64	30.1	21.5
BT-190	Xply	0.64	35.7	24.2

In general, the total counts of single fibers, provided by DPG through post-analysis of sticky paper residue samples (Table 2), agree with the rough category estimates listed in Table 8. The rough estimates given in Table 8 show a direct relationship between original sample size and the amount of single fibers released. The DPG data only does this in a more general manner. Considering the extreme light weight of the 0.16-cm (0.0625-in.) and 0.32-cm (0.125-in.) thick AS/3501-6 plates, the data are remarkably consistent. The 0.32-cm (0.0625-in.) and 0.64-cm (0.250-in.) plates produced almost identical residues, with only a slight difference in particle distribution noted when either unidirectional or crossplied material was tested.

Figures 7 through 10 are photographs depicting residues from this latter group of tests. Note the small amounts of materials encountered in these series of released fibers.

SUMMARY AND CONCLUSIONS

The tests described herein essentially complete the study of major blast effects upon composite aircraft structural elements or basic composite materials. These data are a source of released fiber characteristics and dissemination modes for risk analyses to be performed by others (e.g., DPG, NASA, LaRC). Specific conclusions and observations are as follows:

1. Earlier tests with DC-10 rudder and Boeing 747 spoiler samples were essentially validated from these tests with other structural elements and plate materials. Similar residue distributions were obtained from both sets of test data.

2. Crossply and unidirectional AS/3501-6 samples behaved differently on burning but produced similar residues when subjected to the blast force of 57 g (2 oz) of C-4 explosive.

3. Sample materials of pure fiber and matrix are easier to evaluate than those with additional reinforcements such as aluminum, fiberglass, rivets, etc.

4. Recovery of burn/blast residue from thin cross-sectional material is usually complicated by the fact that weight loss due to fiber oxidation is both unknown and variable. This variability appears frequently within supposedly duplicate test conditions on identical samples.

5. No increased HAVE NAME hazards have been observed during these tests, but final risk assessment is dependent on many other factors also being evaluated by NASA.

RECOMMENDATIONS

1. The relationship between sample thickness, sample construction, and particle release characteristics should be more fully explored under less vigorous agitation conditions. The 57-g explosive blast force used in these tests shows that most samples tested produced similar residues; thus, the extremely high energy released may have masked any subtle differences.

2. Enough material should be supplied for each test series so that burn-only tests can be made for each type of sample to be evaluated. This is especially important when the basic formulation percentages are unavailable.

REFERENCES

1. K. A. Musselman and T. C. Babinsky, *Effects of Fires and Explosions on Aircraft Structural Composites*, Naval Surface Weapons Center Technical Report TR-3563, Dahlgren, Virginia, February 1977.

2. T. C. Babinsky and K. A. Musselman, *Burn/Blast Tests of Aircraft Structural Elements*, Naval Surface Weapons Center Technical Report TR-3897, Dahlgren, Virginia, December 1978.

Figure 7. Residue from Test BT-151/X-115, Fiberite Panel

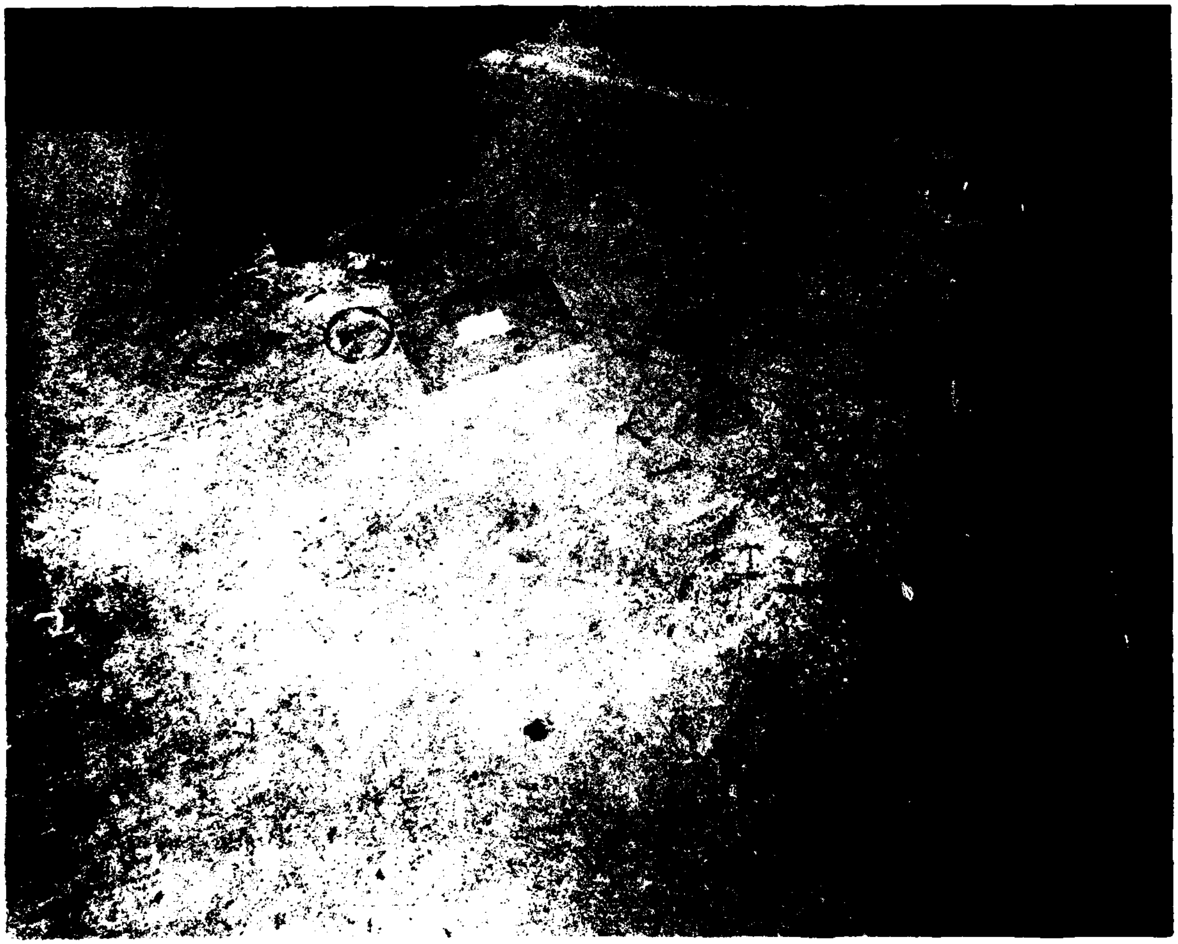


Figure 8. Residue from Test BT-183/X-141, AS/3501-6, Crossply, 15 x 15 x 0.32 cm (6 x 6 x 0.125 in.)

Figure 9. Residue from Test BT-188/X-144, AS/3501-6, Unidirectional, 15 x 15 x 0.64 cm (6 x 6 x 0.250 in.)

Figure 10. Residue from Test BT-189/X-145, AS/3501-6, Crossply, 15 x 15 x 0.64 cm (6 x 6 x 0.250 in.)

APPENDIX A

TEST FIXTURE APPARATUS UTILIZED IN BURN/BLAST TESTING OF COMPOSITE COMPONENTS

The test fixture utilized in all burn/blast testing of composite materials is shown in Figures A-1 and A-2. A 17.8-cm. (7-in.) diameter burner from a hot water heater was utilized (see Figure A-1) to meter the fuel/air ratio and to evenly distribute the flame front over the entire sample surface. Propane was selected as the fuel source. Temperature-profile and fuel-flow calibration measurements established a test configuration of 15.24 cm (6 in.) between the sample and burner at a line pressure of 10,545 kg/m^2 (15 psi) at the gas cylinder. This setting produced a flow rate of 4.086 kg/hr (9 lb/hr) propane. At these temperatures, a uniform and symetrical temperature range of 1038 to 1232°C could be maintained. Temperature was measured 1.3 cm (0.5 in.) below the outer edge of the sample. For 30.5-cm (12-in.) square samples, a temperature gradient of 65°C was typical between the outer edge and the center. Less than a 10°C gradient was observed with the smaller, 15.2-cm (6-in.) square samples.

The explosive weight and type selected for the tests were 57 g (2 oz) of C4 (Harrisite). The material was loaded into an explosive holder and the holder placed in position on the test fixture as depicted in Figure A-2. The holder, shown in Figure A-3 and weighing approximately 11.35 kg (25 lb), was designed to direct the blast evenly at the sample. A X-814 DuPont #8 blasting cap (1A, 1W) was used to detonate the C-4. The explosive holder was positioned 15.2 cm (6 in.) beneath the sample.

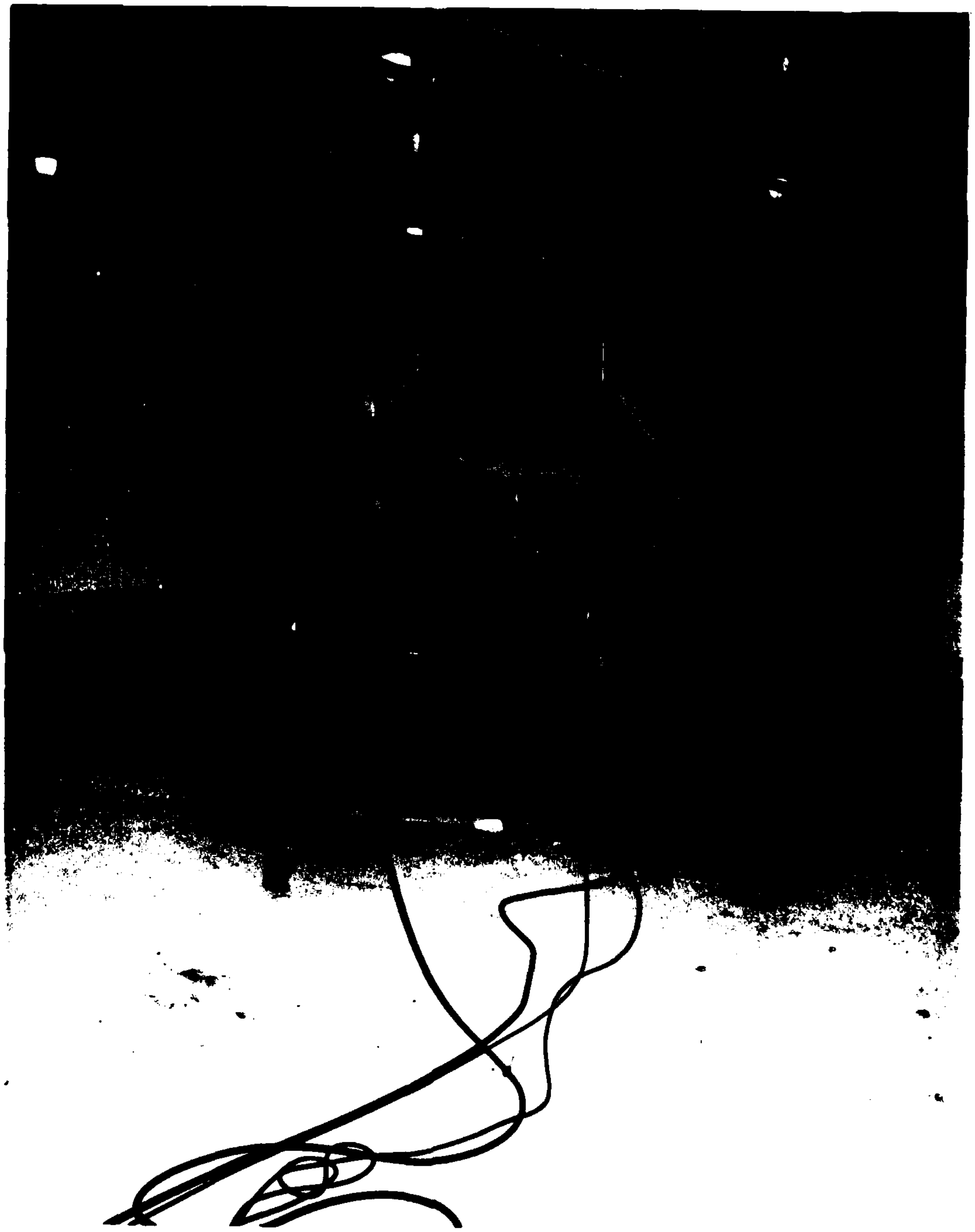


Figure A-1. Test Fixture for Burn/Blast Testing of Composites

Figure A-2. Test Fixture for Burn/Blast Testing of Composites

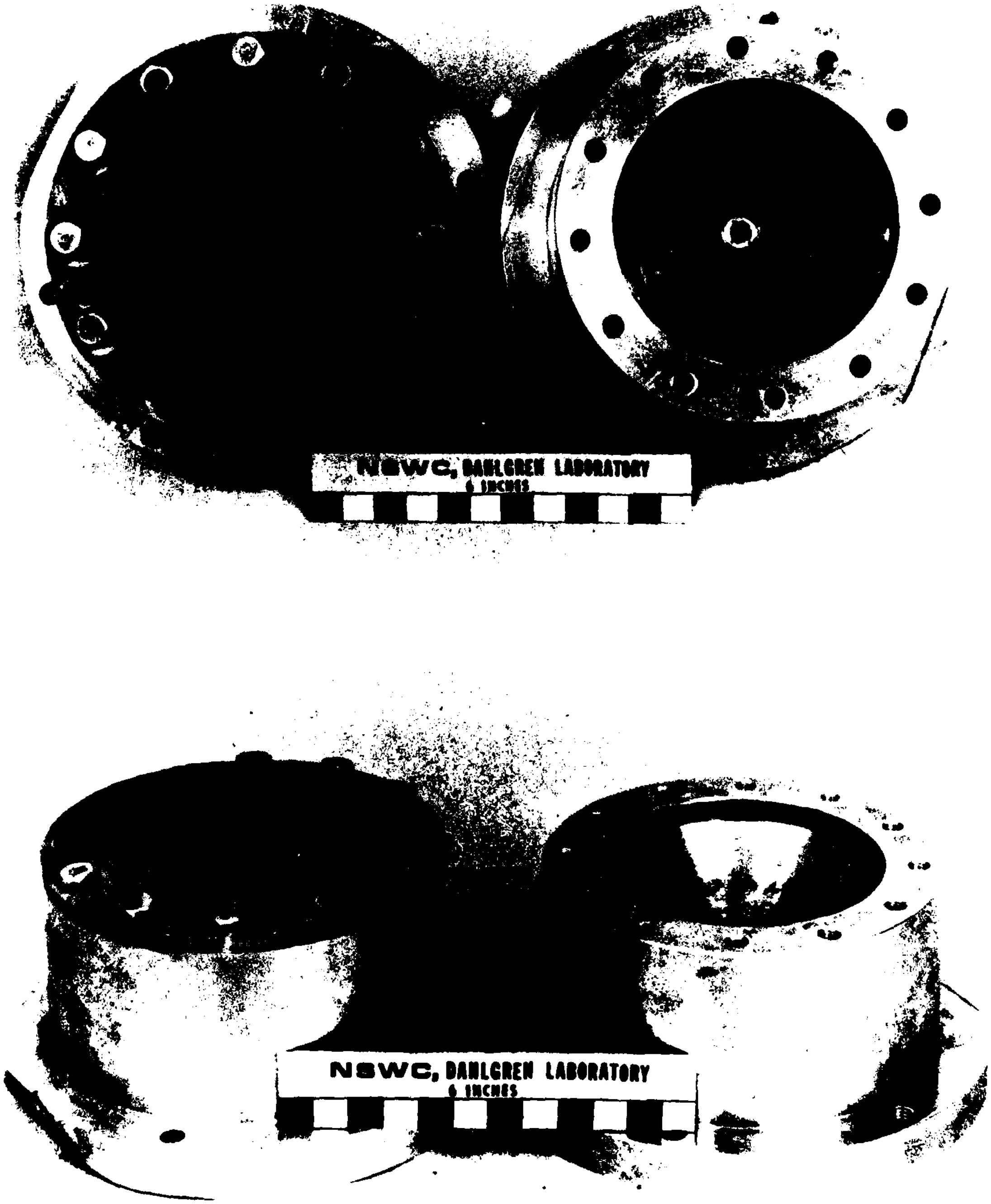


Figure A-3. Explosive Holder

DISTRIBUTION

Chief of Naval Material
Washington, DC 20360
ATTN: NAVMAT 0324 (CDR J. D. Tadlock)

Commander
Naval Air Systems Command
Washington, DC 20360
ATTN: NAVAIR 350 (E. H. Fisher)
NAVAIR 350D (Dr. Wazneski)

Commander
Naval Sea Systems Command
Washington, DC 20360
ATTN: NAVSEA 0351 (C. H. Pohler)

Commander
David W. Taylor Naval Ship Research and Development Center
Annapolis, MD 21402
ATTN: Code 278 (Dr. H. R. Boroson)

Director
Naval Research Laboratory
Washington, DC 20375
ATTN: Code 6170 (Dr. N. L. Jarvis)

Commander, Headquarters
Air Force Systems Command
Andrews AFB, MD 20334
ATTN: XRLW (CAPT L. L. Curtis)

Commander, Headquarters
Electronics Systems Division
Hanscom AFB, MA 01730
ATTN: XRPH (COL P. Tsouprake)
MITRE (Dr. W. W. Vickers)

Commander
Air Force Logistics Command
Wright-Patterson AFB, OH 45433
ATTN: MAXP (Mr. R. Bennett)
MAX (COL M. T. Smith)

DISTRIBUTION (Continued)

Director
Army Ballistic Research Laboratories
Aberdeen Proving Ground, MD 21005
ATTN: AMXBR-PM-H (LTC D. Reinhard)
(Dr. L. J. Vande Kieft)

Commander
Army Materials and Mechanics Research Center
Watertown, MA 02172
ATTN: AMXMR-R (Dr. R. Shuford)

National Aeronautics and Space Administration
Materials Division
Langley Research Center
Hampton, VA 23665
ATTN: Mail Stop 226 (Dr. V. L. Bell) (10)

Defense Technical Information Center
Cameron Station
Alexandria, VA 22314 (12)

Local:

E41	
F56	(5)
G33 (Musselman)	(10)
X210	(6)
X211	(2)